APPENDIX A

Biological Survey Report for the Santa Maria Creek Restoration Project: Stephens' kangaroo rat (Spencer and Montgomery 2007)

Biological Survey Report for the Santa Maria Creek Restoration Project:

Stephens' Kangaroo Rat

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Introduction

The presence of the federally endangered and state threatened Stephens' kangaroo rat (SKR; *Dipodomys stephensi*) within the Ramona Grasslands was documented in October 1997 with initial verification of the species on the Ramona Airport and adjacent lands within the airport planning area (Ogden 1998). Since then, a variety of surveys and observations have confirmed that SKR occupy well-drained loamy soils scattered throughout the grasslands north and east of Santa Maria Creek, which traverses the RGP in an east to west direction for approximately 4.5 miles (7.25 km).

Directed sign surveys were conducted in 2005 and 2006 to map the distribution and relative abundance of SKR in the grasslands and to identify those habitat areas of greatest importance to sustaining the population, as well as those areas most in need of active or passive management for the species. Limited trapping surveys were also conducted in select areas to confirm presence of SKR, as opposed to another, unlisted species of kangaroo rat – the Dulzura kangaroo rat (DKR; *Dipodomys simulans*).

Project Location

Surveys were conducted within a core preserve area known as the Ramona Grasslands Preserve (RGP). RGP is located in the vicinity of the Santa Maria Creek and the Ramona Airport in the western portion of the community of Ramona, San Diego County, California. The preserve area includes properties currently owned by The Nature Conservancy, including the former Cagney Ranch, the Hardy property, Oak Country Estates, and Eagle Ranch. Adjacent landowners, including Wildlife Research Institute (WRI), selected Voorhes Lane properties, Cumming Ranch, the County's Ramona Airport open space, Hobbs, Martz, and the Ramona Water District were given the opportunity to take part in this project. Only properties with landowner consent were included in project activities, although absence of SKR was confirmed for some of these properties based on existing information or reconnaissance from property boundaries.

Most of the properties have been used as livestock pasturage, but were formerly part of a large expanse of native grassland. These locations have been identified by the proposed North County Multiple Species Conservation Program (MSCP) Subarea Plan as areas of very high quality habitat and, as such, have been included in the planned preserve area.

Project Description

The County of San Diego Department of Parks and Recreation was awarded a Proposition 13 Grant by the California Water Resources Control Board for the Santa Maria Creek Protection and Restoration Project. The purpose of the grant is to protect and restore Santa Maria Creek and its adjacent watershed areas within the Ramona Grasslands Preserve, the project area, (hereinafter referred to as "Ramona Grasslands"), to improve water quality and habitat conditions in the creek corridor. Santa Maria Creek has been subjected to unmanaged cattle grazing, which has resulted in elevated suspended sediment concentrations, bacteria, and nutrients in the stream. In addition, increasing urbanization in the town of Ramona, upstream of the project area, has contributed urban, non-point source runoff to the stream. Land uses upstream of the Ramona Grasslands are largely rural residential, but development densities are projected to increase in the future according to General Plan 2020 of the County of San Diego. The Santa Maria Creek Protection and Restoration Project will prevent residential development in the Ramona Grasslands, thus eliminating a future source of urban runoff to Santa Maria Creek and downstream receiving waters. The project will also manage cattle grazing by limiting access of livestock to the creek corridor with fencing, thus eliminating a source of agricultural pollutants and allowing stabilization of the channel and restoration of riparian and wetland vegetation to enhance riverine functions in the creek system.

A second component of the project consists of collecting baseline biological data, which will facilitate preserve management decision-making and track responses to management actions to refine recommended monitoring protocols. Baseline data will enable preserve managers to:

- Measure the success of the non-native plant species removal and restoration program.
- Measure changes in the physical condition and hydrology of the creek, ephemeral aquatic habitats (vernal pools, vernal swale, and alkali playas) and their watersheds.
- Track changes in the current distribution and abundance of management target species.
- Understand the distribution of non-native animal species.
- Provide a benchmark to which all subsequent monitoring data can be compared, realizing that the "typical" and historic conditions of the Grasslands are unknown.

The target species selected for the baseline surveys are the arroyo toad (*Bufo californicus*), riparian bird species, raptors, and Stephens' kangaroo rat (*Dipodomys stephensi*). In addition, vernal pools were surveyed for fairy shrimp, amphibians, and plant species. Grassland floral surveys and vegetation transects across Santa Maria Creek were also performed. The following sections describe the methods and results of the SKR surveys in 2005-2006 as well as recommendations for future monitoring and management.

Methods

SKR Distribution

A primary aim of this study was to create a comprehensive SKR distribution map for the RGP to inform future management and monitoring actions. This was accomplished by surveying all properties we had access to for signs of kangaroo rat occupancy, supplemented by existing information from adjacent properties, most notably the Ramona Airport. Some adjacent properties are also known from previous surveys not to support SKR or suitable habitat (e.g., Cumming Ranch; O'Farrell 2000a, 2004). SKR absence was likewise inferred for some properties on which we were not granted access (e.g., Hobbs and the "Voorhes Lane properties") based on lack of suitable habitat, as indicated by inspection of aerial photographs and ground-truthing from property boundaries. However, we did not attempt to map SKR distribution on some properties that are known to support SKR based on previous trapping surveys (P. Vergne, unpublished data), but that we could not confidently map without access (e.g., Martz and Ramona Water District ownerships). Figure 1 summarizes these different forms of SKR assessment, including those areas surveyed in the field for this effort, those previously surveyed by others, and those areas on which SKR distribution was not mapped.

On RGP properties with access, distribution and relative abundance of SKR were mapped in the field by Wayne Spencer and Stephen Montgomery, with assistance from Esther Rubin and Scott Tremor (Table 1). During 2005, surveys covered properties included in the RGP at that time (Cagney, Hardy, and Oak Country Estates). Eagle Ranch was added to the reserve area in December 2005 and therefore surveyed for SKR during 2006. During 2006 we also spot-checked a number of areas previously surveyed during 2005 to confirm that SKR distribution had not changed notably from one year to the next, so that we could treat the composite 2005-6 map as one consistent baseline data source.

The mapping method involved walking meandering transects over the entire area (at no greater than 50-m spacing) searching for signs of SKR occupancy (burrows, scats, tracks, dust baths). Once signs of occupancy were found in a particular location, the biologists searched for the outer perimeter of the occupied area (where no further sign could be found, or where habitat clearly became unsuitable), enclosed it with a polygon, and classified the relative density of SKR burrows within the polygon using density classes originally developed by M. O'Farrell (1992) and modified by S. Montgomery for ease in mapping at finer resolution (Table 2). Results were marked onto 1:3200-scale, true-color aerial photographs. Mapping was aided by having the aerials divided into grids with 50 x 50-m cells and by use of GPS.

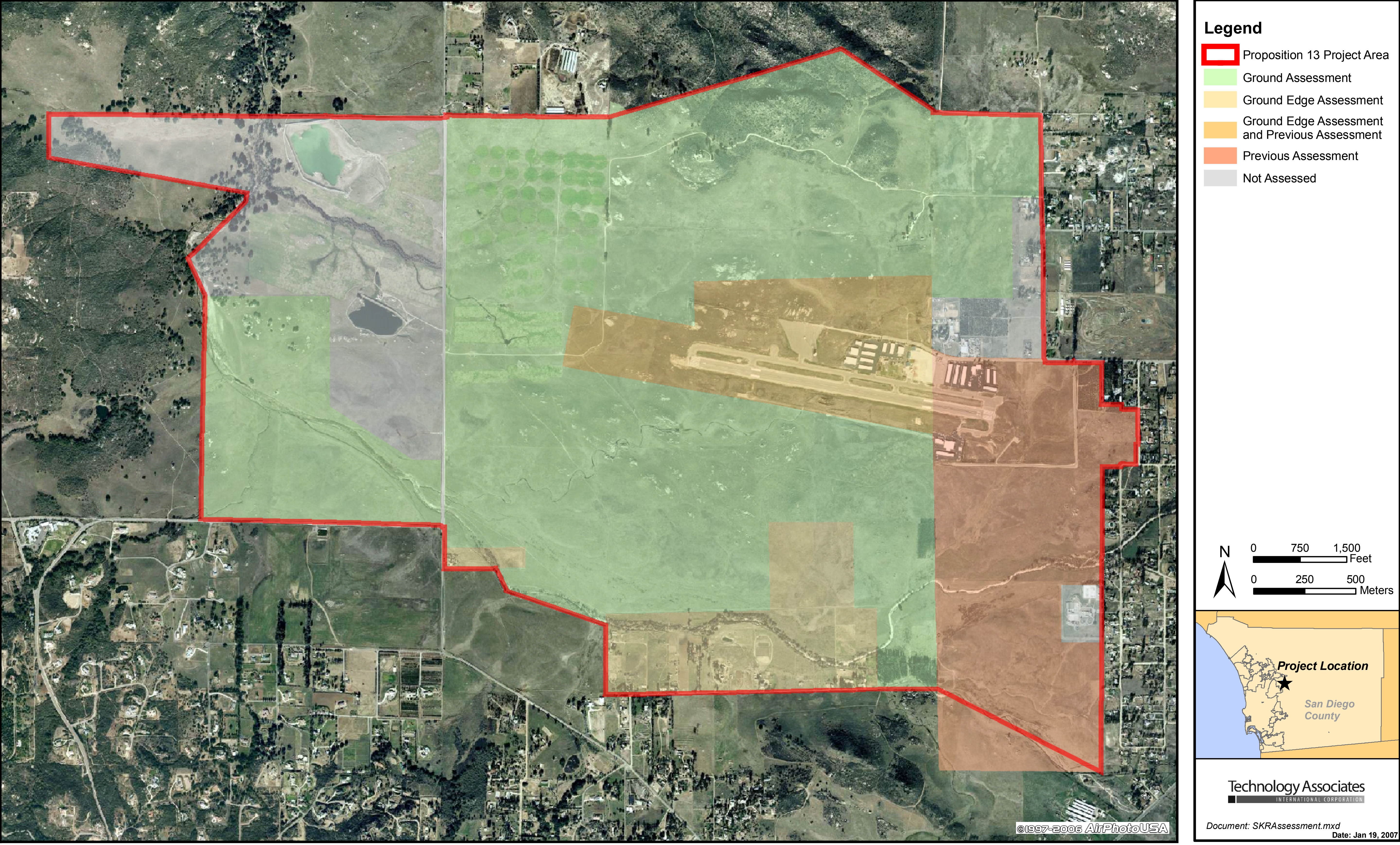


Figure 1 - Stephens' Kangaroo Rat Survey Areas

Table 1. SKR distribution survey dates and areas surveyed.

Date	**Observers**	**Area Surveyed**
2005		
23-Sep	WS, SJM	North and west Oak Country Estates
12-Nov	WS, SJM	East end Cagney, Hardy
19-Nov	WS SJM	Central Cagney
17-Dec	WS, ST	South Cagney, south and central Oak Country Estates
2006		
25-Aug	WS	Southwest Eagle Ranch and spot checks on Cagney
5-Sep	WS, SJM, ER	Central and north Eagle Ranch and spot checks on Oak Country Estates
6-Sep	WS, SJM, ER	North and northeast Eagle Ranch
8-Sep	WS, SJM, ER	South and central Eagle Ranch and spot checks
26-Oct	WS	West-central Eagle Ranch and spot checks on airport, Cagney
26-Oct	WS	Northwest Eagle Ranch and spot checks on Cagney

Table 2 SKR burrow density classes as originally defined by O'Farrell (1992) and as scaled down for finer-resolution mapping in the field by S. Montgomery.

Density Class	Burrows/ha (O'Farrell)	Burrows/200 m^2 (Montgomery)
Trace	<50	<1
Low	50-200	1-4
Moderate	200-700	4-14
High	>700	>14

Note that these density classes are often combined by field biologists into two broader classes (Trace/Low and Medium/High) to increase survey efficiency and repeatability (i.e., it is easier to confidently assign density estimates using broader classes). However, for this survey, we retained the finer-resolution categories, in part to better discriminate the baseline information for statistical comparisons, and in part because SKR densities were so low during the survey years that the difference between trace and low density seemed biologically significant. Most occupied habitat supported only trace SKR densities; moderate-density areas were very rare, and there were no high density areas to map.

We also mapped SKR density at the edges of the Ramona Airport, and incorporated and edge-matched distribution and density mapping performed on the Airport property in 2005 by Haas and O'Farrell (2005). In incorporating the airport data, we converted Haas and O'Farrell's polygons to a similar mapping resolution and applied the same density classes as done on RGP, calibrating and adjusting polygons near the Airport boundary as necessary based on our own observations.

In addition to survey dates listed in Table 1, which all reflect ideal sign-survey conditions during late summer-fall, W. Spencer also spot-checked portions of the study area during winter-spring conditions on 26 January and 28 April 2006. Considered together, all these observations indicated that SKR populations were very low but relatively stable over the study period, with little evidence of population expansion or contraction during 2005-6 (but following a dramatic contraction from 2004 to 2005; Haas and O'Farrell 2005). Note that the winter of 2004-5 was the wettest on record at the Ramona Airport (29.03 inches of rain), which led to extraordinary growth of grasses during 2005. As discussed in more detail below, the SKR population contracted in response to this change in vegetation, with SKR persisting only in the most well-drained and highly suitable soils. The population did not appear to expand significantly in the drier conditions of 2006. Consequently, although gathered over two consecutive years, the survey results can reasonably be treated as one uniform coverage that can serve as a baseline for future monitoring and management.

Trapping

Limited trapping surveys were performed in portions of the RPG to confirm which species of kangaroo rat was present, the endangered SKR or the non-listed Dulzura kangaroo rat (*Dipodomys simulans;* DKR; formerly *D. agilis*). Although these two species sometimes co-occur at a local scale, SKR are competitively dominant and almost always occupy the most open grassland habitats, whereas DKR are generally restricted to those areas with some scrub cover (Price et al. 1991). Previous intensive trapping surveys in the Ramona Grasslands (e.g., Ogden 1998, Spencer 2002, P. Vergne unpublished data) have repeatedly reinforced these observations, with only SKR found in the open grasslands but either species occupying grass/scrub interface areas, and predominantly DKR in open scrub habitats or oak savannahs.. Consequently, we sample-trapped to identify which of the two species was present in scrub interface areas and to refine our mapping of SKR-occupied habitat areas. These were not USFWS "protocol" surveys intended to verify absence of SKR, but rather spot-sampling efforts to refine our understanding of SKR distribution in areas of uncertainty. We did not attempt to use trapping surveys to quantify SKR density, because SKR are too highly variable in trap response to make this method reliable (Diffendorfer and Deutschman 2002, O'Farrell 1992), and such surveys are very expensive for the quantity and quality of data returns.

Trapping was performed under S. Montgomery's state and federal permits for SKR. Sherman live traps were baited with mixed bird seed and set at dusk in meandering transects where either or both species could be present. Trapping was done on the nights of September 6 and October 25-27, with traps checked both around midnight and again at dawn. Captured animals were sexed, aged, and measured with standard techniques, and released on site.

Delineation of Core SKR Management Areas

Once SKR distribution and relative density were mapped, W. Spencer delineated Core SKR Management Areas based on observed SKR occupancy patterns, habitat conditions, and spatial context. The core areas enclose relatively large mosaics of mostly suitable habitat that are likely to continue supporting SKR in all years and which may be sources of dispersing SKR during years of population expansion. Vegetation management (e.g., prescribed burns) is therefore most likely to benefit the population if applied strategically within or between these core management areas, rather than in outlying areas where conditions may remain unsuitable even with management.

Habitat Analyses

Previous studies (e.g., Spencer 2003, O'Farrell and Uptain 1987) have established relationships between certain characteristics of grassland vegetation, measured during late summer-fall, and SKR habitat quality--at least during dry years. For this study, we attempted to further verify and expand on these previously established patterns (specifically, positive associations of SKR density with proportion of bare ground and forb:grass ratio, and negative associations with vegetation density and abundance of annual grasses). We also tried to derive an earlier spring measure of vegetation condition to inform management decisions. Early season indicators (or triggers) for management would be useful, so that management intervention to counter over-dense annual grass growth could be implemented before it is too late.

We first looked for statistical differences between observed SKR density classes (zero, trace, low, moderate) and between subjectively assigned habitat quality classes (no, low, high) using a variety of vegetation variables derived from the vegetation plot sampling data from 2005 and 2006 (CBI 2007). In addition to investigating the vegetation variables mentioned above, we also tested for differences among habitat classes using percent grass, percent forb, percent Erodium, percent thatch, and vegetation height. The vegetation plots were grouped by which SKR density class or habitat quality class they fell within, and statistical comparisons were made between classes for each independent variable using Kruskal-Wallis one-way analysis of variance.

Finally, in hopes that early season standing biomass might be a meaningful habitat measure, we also looked for correlations between SKR density (and habitat quality) classes and standing biomass measures made by Zach Principe (TNC vegetation management expert) during winter-spring conditions.

Results

SKR Distribution

Figure 2 shows the composite SKR distribution map for 2005-06, including SKR density classes for occupied areas, as well as potentially occupiable habitat areas within which we did not observe kangaroo rat sign. In total, 165.9 acres of occupied SKR habitat were mapped over the RPG, including the Airport property but excluding the Martz and Ramona Water District properties. Of this total occupied area, 115.3 acres were mapped as supporting trace densities, 43.7 acres as low, 7.0 as moderate, and zero as high.

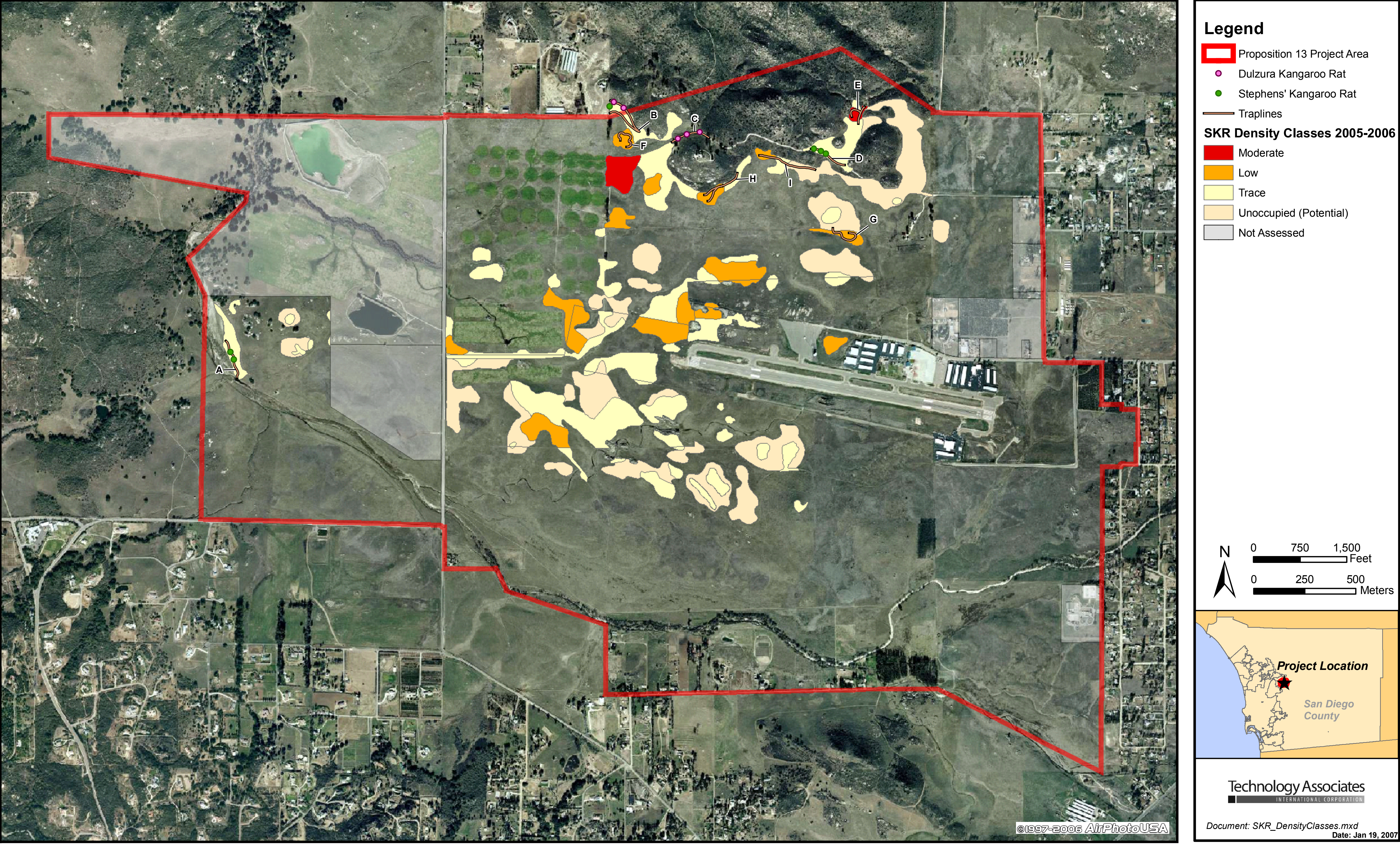


Figure 2 - Stephens' Kangaroo Rat Distribution and Capture Locations

An additional 112.7 acres were mapped as potential habitat that was not occupied during the surveys, or was occupied at such low levels that we did not detect kangaroo rat sign there.

The majority of suitable and occupied SKR habitat is distributed in a broad, arcing mosaic of mostly well-drained, hilly topography near the center of the grasslands, with smaller mosaics or isolated pockets of suitable habitat scattered in other areas. The largest, most contiguous concentration curves around the west end of the airport (which would have been SKR habitat prior to airport development and runway expansion) and extends west to Rangeland Road in those areas not used as effluent spray fields.

A second concentration of SKR habitat occurs in association with the northern fringe of the grasslands, where hills supporting coastal sage scrub rise up from the grasslands on the northern portion of Eagle Ranch. It appears that at least some of this "northern fringe" habitat was created or improved by previous disking or clearing of coastal sage scrub to increase grazing value for cattle (note, for example, the donut-shaped area of potential habitat surrounding a coastal sage scrub hill near the northeastern corner of the study area in Figure 2). Both SKR and DKR were captured in this northern fringe area (Figure 2), with SKR occurring in the more open or down-slope portions, and DKR more in the edges of the coastal sage scrub and along a dirt road through sage scrub. Some habitat polygons found to have sign of kangaroo rats in this area were therefore omitted from Figure 2 and from SKR habitat acreages, as we concluded they were unlikely to support SKR and highly likely to support DKR.

Smaller and more isolated pockets of habitat are found outside these two primary concentrations or core areas of habitat. On TNC/Oak Country Estates, we captured SKR on a broad sandy flood plain near Santa Maria Creek, which we mapped as occupied at trace densities (although it may qualify as occupied at low densities). We also mapped several small pockets of trace or potential SKR habitat on and around isolated rocky hills on Oak Country Estates (aka "Highland Valley Estates"), where M. O'Farrell has confirmed SKR presence during previous trapping surveys (O'Farrell 2000b, 2002). Other isolated pockets of trace-occupied or potential habitat are also associated with rocky hills rising out of less suitable clay soils on portions of Cagney and Eagle Ranch, including some between the effluent spray fields.

The most densely occupied areas we found (e.g., two moderate-density polygons in the northern fringe area) correspond with areas of highly suitable soils, presence of dirt roads, and other disturbances that reduce grass density, such as heavier than average grazing intensity. The largest polygon of moderate SKR density is on a well-drained rocky hill nestled in a bend in the main dirt road and near a watering trough and cattle trails.

Most areas mapped as unsuitable for SKR consist of heavier clay soils, such as eastern portions of Cagney and Eagle Ranch, much of Oak Country Estates, and all of the Hardy and Cummins properties. Heavier clay soils also separate the large mosaic of habitat in the middle of the grasslands from the occupied areas along the northern fringe.

Loose alluvial soils in the floodplain of Santa Maria Creek in the southern part of Cagney Ranch are also not occupied by SKR. This may be attributed to one or more of the following hypotheses: (1) these very loose, sandy soils may not be able to sustain SKR burrows, which may collapse easily in them; (2) occasional flooding by Santa Maria Creek may eliminate SKR from the area (drowning, wetting, and displacement); and (3) denser than average growth of annual grasses and associated thatch, perhaps due to lesser grazing intensity or elevated ground water.

Note that the creation of the effluent spray fields in the western portions of Eagle Ranch apparently rendered some previously suitable habitat unsuitable, due to saturation of the soil and creation of dense, irrigated vegetation. Previously the mosaic of occupied habitat patches was probably more contiguous through this area. Although a few pockets of well-drained soils between the sprayfields are currently occupied, and more areas are probably occupied in years of expanded SKR populations, for the most part the interstices between spray fields appear to be somewhat degraded in habitat quality due to drifting spray, which elevates soil moisture relative to natural conditions. Only the larger and better drained rises between spray fields are therefore likely to reliably support SKR from year to year.

Trapping

A total of 6 SKR and 6 DKR was captured during 3 nights of trapping (Figure 2 and Table 3). Capture locations confirmed prior expectations about the relative distribution of these species in the study area, with DKR found in or closer to areas of open coastal sage scrub, and the SKR in more open and extensive grasslands. Both species were captured on Trapline B (Figure 2), which winds in and out of the grassland-coastal scrub edge at the western-most extent of the "northern fringe" of habitat on Eagle Ranch. The SKR captured here was in the most open and heavily grazed part of the trapline, whereas the 2 DKR were captured in sparse coastal sage scrub slightly farther up the hill. P. Vergne (unpublished data) has also captured both species in this vicinity. Farther east along the northern fringe, only DKR were captured where the dirt road traverses coastal sage scrub (Trapline C); and only SKR were captured even farther east along the road, where coastal sage scrub appears to have been disked to increase pasturage (Trapline D).

Although the total number of kangaroo captures is limited, and no kangaroo rats were captured on some traplines, these results, in concert with previous trapping in various portions of the RGP, helped us to confidently delineate SKR habitat vs. DKR habitat. One exception to this is the easternmost portions of the "northern fringe," where occupied kangaroo rat habitat wraps around a coastal sage scrub hill. We suspect this area is mostly occupied by DKR, but SKR may also be present.

In addition to the kangaroo rats, two adult San Diego pocket mice (*Chaetodipus fallax*) and four deer mice (*Peromyscus maniculatus*) were captured in shrubby and rocky areas on various trap lines.

Table 3. Captures of SKR and DKR during 2006.

Date	Trapline	NUMBER OF TRAPS SET	ANIMALS CAPTURED SKR	ANIMALS CAPTURED DKR
6-Sep-06	A	30	0	0
	B	25	0	0
	C	30	0	1 adult male
	D	30	0	0
	E	25	0	0
26-Oct-2006	A	32	1 adult female, lactating 1 juvenile female	0
	B	23	0	1 adult female
	C	17	0	2 adult males 1 adult female
	D	15	1 adult female	0
	E	26	0	0
	F	25	0	0
	G	15	0	0
27-Oct-06	B	23	1 adult male, scrotal	1 adult male, scrotal
	D	15	1 adult male, scrotal 1 adult female	0
	E	26	0	0
	F	25	0	0
	G	15	0	0
	H	25	0	0
	I	25	0	0

Weather Conditions:

6/SEPT - ~0730, 70deg.F, 0-3mph, clear skies, moon ~full
25/26 OCT - ~1100 to 0100, 50-58F, 0mph, clear, moon near dark (new) ~0630, 60F, 4-10mph, clear
26/27 OCT - ~1045 to 0000, 66F, 5-15mph, clear, moon a sliver ~0630, 68F, 5-15mph, clear

Habitat Analyses

During 2005, there were no statistically significant correlations between any of the vegetation variables and either SKR habitat quality or density due to very low sample sizes (only four vegetation plots landed within occupied SKR polygons) and due to the extreme growth of grasses in nearly all areas (due to record winter rains). The proportion of vegetation plots in bare ground or forbs was exceptionally low across all plots in 2005, as grasses grew extremely dense, thus swamping out forb growth and obscuring differences among plots in those variables most predictive of SKR habitat value, such as percent bare ground and the forb:grass ratio (O'Farrell and Uptain 1987, Spencer 2003).

Table 4. Means and standard errors for vegetation measurements on sample plots falling within polygons of different SKR density classes (top) or habitat quality classes (bottom) during 2005. No vegetation plots fell within low, medium, or high density classes.

2005	SKR Density Class						
Variable	**none**		**trace**		**low**	**medium**	**high**
-	Mean	SE	Mean	SE			-
Biomass (lbs/ac)	2910	877	2724	1218			
%Grass	58.1%	0.022	53.7%	0.028			
%Forb	37.9%	0.018	40.7%	0.024			
Forb:Grass Ratio	0.67	0.054	0.77	0.089			
% Bare Ground	3.6%	0.007	4.0%	0.005			
% Erodium	25.4%	0.014	29.6%	0.015			

	Habitat Quality					
Variable	**High**		**Medium**		**Low**	
-	Mean	SE	Mean	SE	Mean	SE
Biomass (lbs/ac)	1915	723	2564	1147	30410	1075
%Grass	49.8%	0.036	55.0%	0.017	59.2%	0.025
%Forb	43.0%	0.047	40.4%	0.012	37.0%	0.021
Forb:Grass Ratio	0.88	0.157	0.74	0.043	0.65	0.062
% Bare Ground	4.4%	0.006	4.4%	0.008	3.3%	0.008
% Erodium	32.1%	0.005	25.9%	0.012	25.5%	0.017

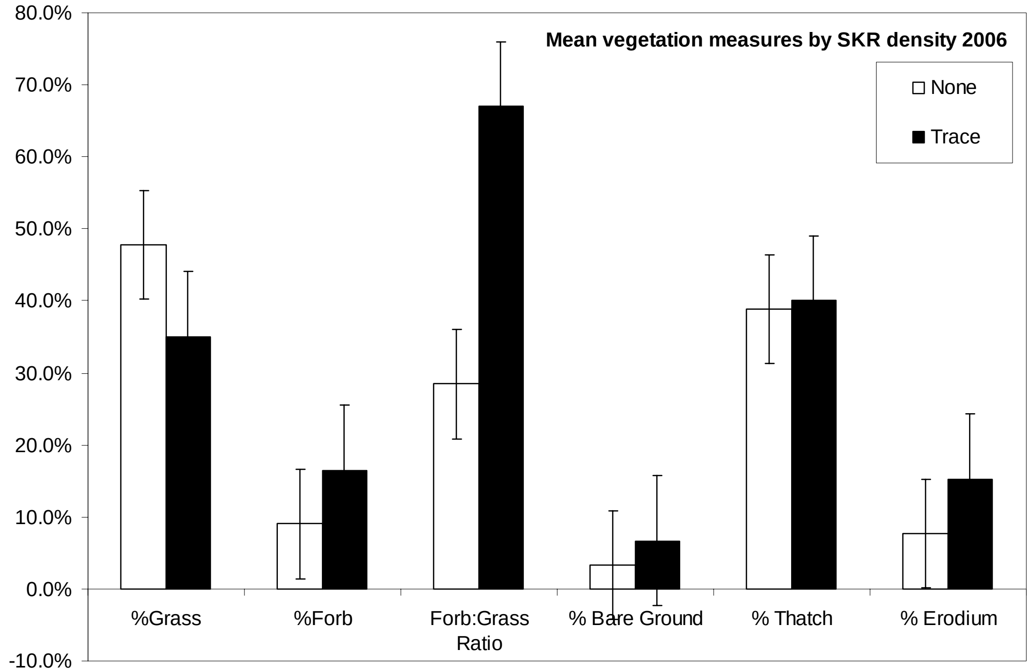
Table 5. Means and standard errors for vegetation measurements on sample plots falling within polygons of different SKR density classes (top) or habitat quality classes (bottom) during 2006. No vegetation plots fell within low, medium, or high density classes.

2006	SKR Density Class						
Variable	**none**		**trace**		**low**	**medium**	**high**
-	Mean	SE	Mean	SE			-
Biomass (lbs/ac)	2457	614	2349	959			
%Grass	47.8%	0.025	35.1%	0.056			
%Forb	9.0%	0.019	16.5%	0.043			
Forb:Grass Ratio	0.28	0.131	0.67	0.252			
% Bare Ground	3.4%	0.007	6.7%	0.019			
% Thatch	38.8%	0.010	40.0%	0.013			
% Erodium	7.7%	0.020	15.2%	0.038			

	Habitat Quality					
Variable	**High**		**Medium**		**Low**	
-	Mean	SE	Mean	SE	Mean	SE
Biomass (lbs/ac)	2256	1128	2310	1155	2510	671
%Grass	33.2%	0.077	35.2%	0.082	50.1%	0.013
%Forb	17.8%	0.052	15.7%	0.075	7.8%	0.012
Forb:Grass Ratio	0.78	0.352	0.79	0.507	0.16	0.030
% Bare Ground	6.1%	0.029	6.0%	0.018	3.2%	0.008
% Thatch	41.2%	0.014	41.8%	0.027	37.8%	0.008
% Erodium	16.9%	0.047	14.5%	0.071	6.3%	0.012

In contrast, significant or nearly significant differences were found for some predictor variables in 2006 (Figure 3) despite very low sample sizes (only six vegetation plots fell within trace-occupied SKR areas and eight within suitable habitat, with no plots falling within areas occupied at higher than trace densities). Vegetation plots falling within areas occupied by SKR had significantly less grass cover than those not occupied by SKR ($P = 0.039$). Although the very low sample sizes also resulted in non-significant ($P > 0.1$) differences for other variables, the trends tend to support prior findings for differences in habitat quality and SKR density (O'Farrell and Uptain 1987, Spencer 2003). For example, during 2006, plots in areas occupied by SKR averaged twice as much bare ground as those unoccupied by SKR(6.7% vs. 3.4%; Figure 3 top), although bare ground was relatively rare nearly everywhere and low sample sizes resulted in non-significant statistical tests. Likewise, the average forb:grass ratio averaged 0.67 in occupied areas versus only 0.28 in unoccupied areas, although again this difference was not statistically significant ($P = 0.122$). Similar weak or not-quite-significant results were found between areas of low vs. medium-high SKR habitat quality as for SKR density. For example, the forb:grass ratio for medium- and high-value habitats were 0.79 and 0.78, compared with average forb:grass ratio of only 0.16 for low-value habitats (Figure 3 bottom), although again the difference was not statistically significant ($P = 0.116$) using Kruskal-Wallis analysis of variance.

Finally, no statistically significant contrasts were possible for the winter-spring biomass measurements (due to small sample sizes and large inter-plot variance), although visual inspection of the results suggest that a threshold biomass of about 3,000 lbs/ac is indicative of poor quality habitat, particularly in 2006 (Figure 4). Note that although there is wide overlap in biomass measurements between density and quality classes, there are clear trends in increasing quality and density with decreasing standing biomass. Perhaps more important, the variance in biomass measurements declines with habitat quality, such that, while poor quality habitats cover the full range of biomass measurements, the better SKR habitats tend to be confined to the low end of the spectrum (below about 3,000 lbs/ac).



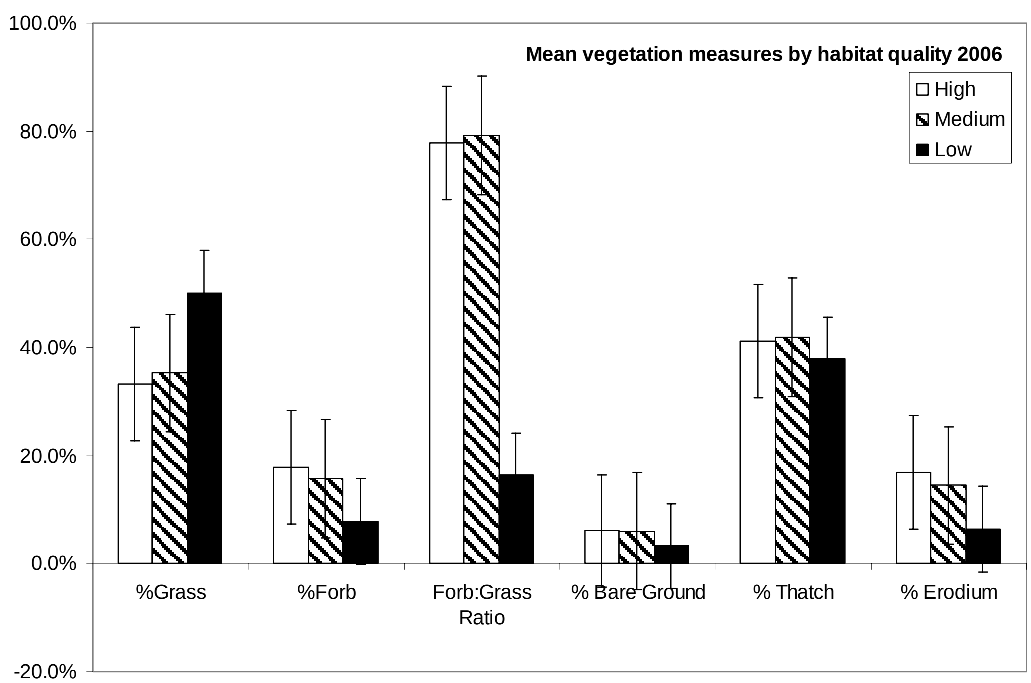
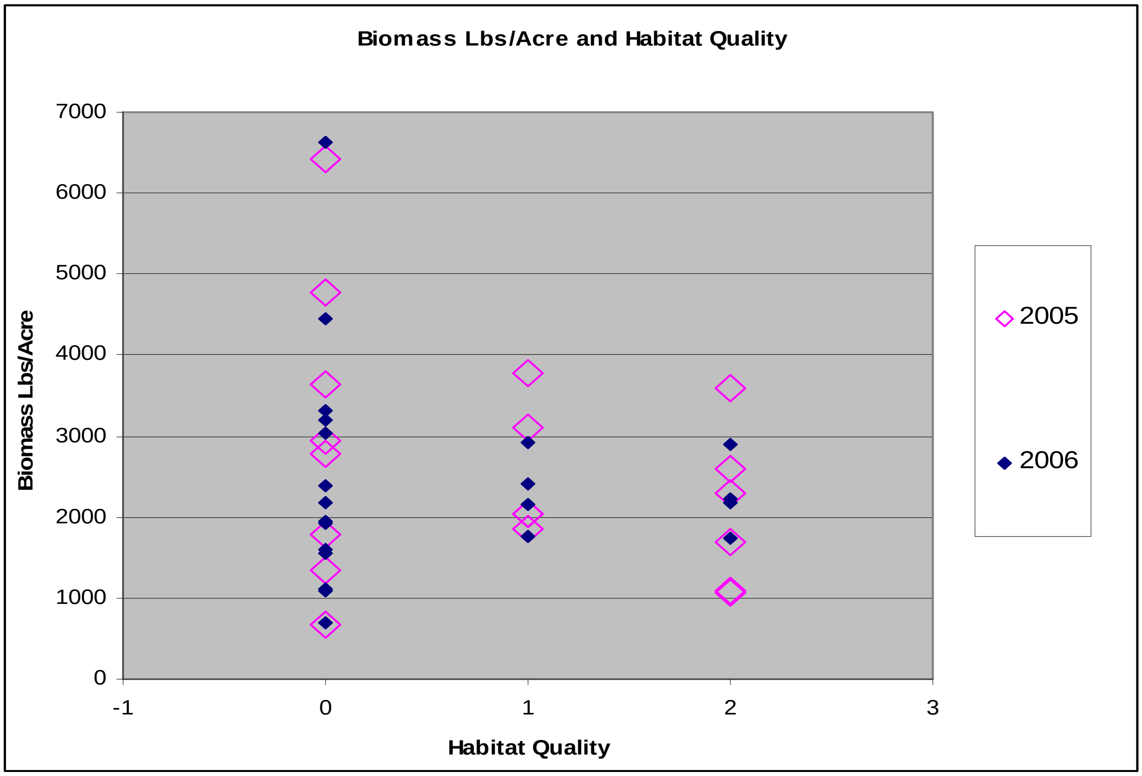


Figure 3. Vegetation measures from sample plots within areas differing in SKR density (top) and habitat quality (bottom) during 2006 (means $\pm$ SE).



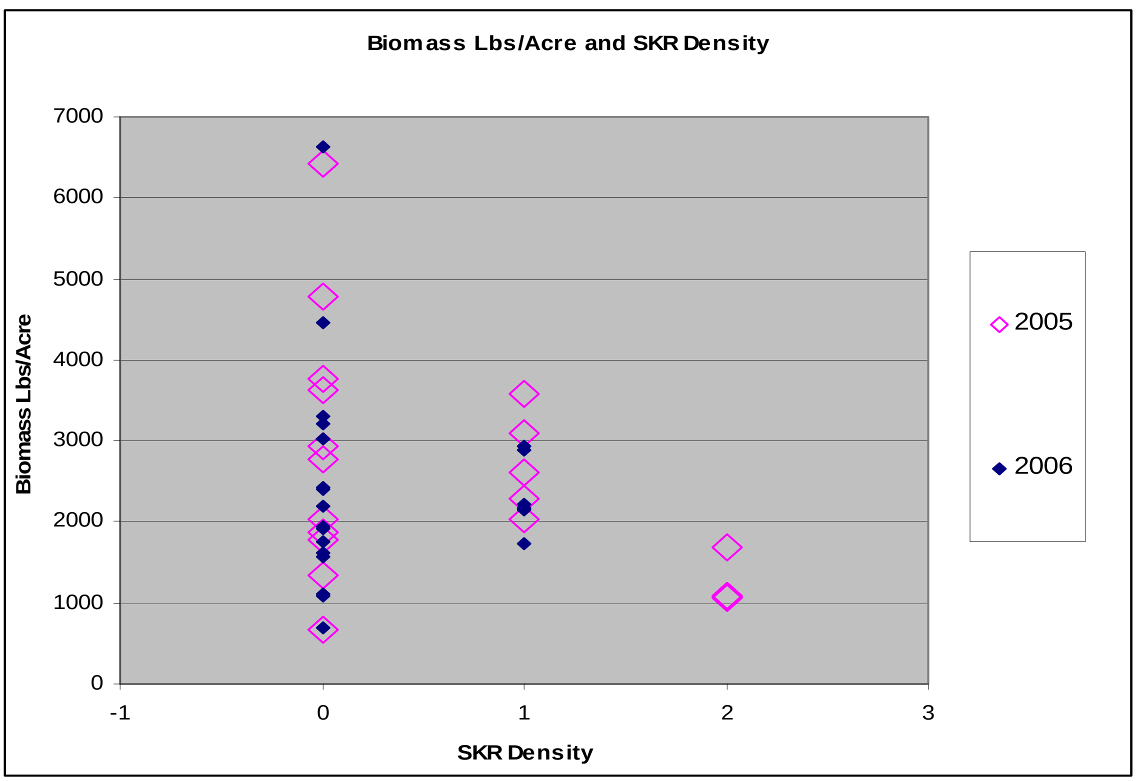


Figure 4. Standing biomass at plots falling within different SKR density classes (top) and habitat qualities (bottom) in 2005 and 2006. (For habitat quality, 0 = low, 1 = moderate, and 2 = high; for SKR density, 0 = none, 1 = trace, 2 = low.)

Discussion

SKR Distribution and Abundance

Observations and quantitative measurements of SKR populations over the past decade in the RGP (especially on the airport property) paint a consistent picture of how SKR distribution and abundance change in relation to precipitation, vegetation growth, soil characteristics, and disturbance factors (Haas and O'Farrell 2005, Spencer 2003, Conservation Biology Institute 2004): Both distribution and density tend to shrink during periods of high vegetation growth (high soil moisture) due to increases in the density of grass and associated thatch, which impede SKR movements and may decrease food availability by out-competing annual forbs that provide preferred seeds. Those areas occupied by SKR during such years tend to be those on the best-drained soils (and/or more heavily disturbed areas), which tend to be reliably occupied year after year. In drier years with more sparse vegetation, SKR populations tend to expand and may re-occupy areas of less well-drained soils or lesser disturbance, only to shrink back again when vegetation again becomes too dense in these areas.

On the airport property, some areas of highly suitable soils have been occupied by moderate to dense SKR populations every year since 1997 (e.g., highly suitable soils and vegetation northwest of the airport runway). Other areas, of intermediate soils quality (e.g., loams with a higher proportion of clays), are occupied in good years, but not in bad years (especially if grazing pressure or other vegetation disturbance is low). Areas with the most heavy clay or hydric soils are never or very rarely occupied, regardless of weather patterns or disturbance history. Thus, even in the wettest years on record, SKR populations appear to persist in scattered areas possessing the most suitable, well-drained soils (generally sandy loams on the upper portions of hills, around rocky outcrops). These "core" habitat areas appear to serve as sources of dispersing individuals to colonize intermediate-value areas during dry years, or even during wet years if they are properly managed to reduce invasions by annual grasses and thatch (using grazing, fire, or other disturbance). Since conditions appear to be most limiting to SKR in wet years, those areas occupied by SKR following a wet winter appear to be occupied fairly continuously in wet as well as dry years, and therefore seem to contribute most to population persistence.

The record rains of 2004-5 resulted in the lowest observed distribution and abundance of SKR on the Ramona Airport property since SKR were discovered there in 1997 (Haas and O'Farrell 2005, CBI 2004). The survey years 2005-06 were therefore ideal for mapping the distribution and relative abundance of SKR at their lowest levels, when SKR distribution appears to most accurately reflect habitat quality. Even areas found to support low densities during this study period appear to be indicative of high habitat values, and are expected to support moderate to high densities of SKR in years of population increase. Areas mapped as potential habitat, but where we could find no sign of SKR occupancy during this population low, are also likely occupied during some years, especially when population levels are higher. Indeed some areas mapped as potential habitat, as well as some mapped as non-habitat during this study, were occupied by SKR in previous years (Ogden 1998). Consequently we believe the 2005-6 distribution map (Figure 2) serves as a useful baseline for future monitoring and management efforts, recognizing that populations are likely to expand into areas outside those we found to be suitable during 2005-6.

Grazing, fire, or other disturbance factors appear to moderate the severity of population fluctuations on the areas of intermediate soils quality, by reducing the density of annual grasses and thatch and favoring growth of annual forbs (such as *Erodium* spp.), which provide SKR a favored food source while not impeding movements as severely as annual grasses do (because they dry and disarticulate by late spring to create the open conditions SKR prefer during breeding season). Thus, grazing or fire promote good habitat quality and relatively high SKR densities on moderately well-drained soils even during wet years, and can help maintain larger populations in and surrounding the best, "core" habitat areas.

SKR have also benefited to some degree by creation of roads and heavily used cattle trails in the RGP (see for example, the linear area of occupied habitat connecting east-west from west of the airport runway to Rangeland road, which corresponds with the main access road used by the ranchers). The fairly large polygon of moderate-density SKR occupancy on Eagle Ranch (the highest recorded density during this study) is on a well-drained rocky hill nestled in a bend in the main dirt road and near a watering trough (the red polygon at the western end of the "northern fringe" in Figure 2). This area combines highly suitable soils with higher than average cattle use, and with good connectivity to other habitat areas via dirt roads and cattle trails. Such confluences of positive factors appear to create high quality and relatively densely occupied pockets of SKR habitat.

Core SKR Management Areas

The two core SKR management areas delineated in Figure 5 should be focal areas for monitoring SKR populations and habitat and for instituting vegetation management measures when conditions suggest this is necessary. Vegetation management (e.g., managed grazing or prescribed burns) is most likely to benefit the population if applied strategically within these core management areas, rather than in outlying areas where conditions may remain unsuitable even with management, or where suitable habitat is distributed in smaller and more isolated patches. Thus, although SKR are found outside these core areas (especially during periods of SKR population expansion), vegetation management outside the core areas is less likely to contribute to overall SKR population viability or long-term persistence, since SKR in such locations will apparently always be vulnerable to extirpation during poor (e.g., wet) years.

Although the two core areas share many similarities, they differ somewhat in ecological context and may require slightly different management approaches. The larger core area 1 (with about 182 acres of suitable habitat) occupies the heart of the grasslands, on hills and around rocky outcrops that rise up from lower lying grasslands on soils higher in clay content. Although portions of this core area support sparse coastal sage scrub (e.g., on the northwest portions of the airport property), for the most part the high quality SKR habitats in this core will likely continue supporting grassland vegetation (and suitable SKR conditions) under most grazing regimes and weather conditions. However, a significant decrease in SKR habitat quality here (for example, if consecutive wet years and reduced grazing pressure led to greatly increased grass and thatch density) could greatly increase the potential for SKR extirpation from the RGP and would need to be countered by active management.

The smaller core area 2 (with about 74 acres of suitable habitat) is associated with the coastal sage scrub-grassland interface at the northern fringe of the RGP. Much of the high quality SKR habitat in this core appears to have resulted from previous clearing of coastal sage scrub to increase cattle pasturage. Unless grazing pressure remains relatively high in this area, or vegetation is occasionally disked or otherwise managed to resist shrub encroachment, some occupied habitats in this area may revert to a denser sage scrub community—thus excluding SKR. Although this may incrementally reduce the amount of available SKR habitat and SKR population size in the RGP, it may not significantly reduce SKR population viability in the RGP. Management that allows for some natural increase in coastal sage scrub vegetation in this core area may not be overly detrimental to SKR, and may benefit other species living in the area, such as California gnatcatchers (*Polioptila californica*).

The land between these two management cores consists of lower lying, heavier clay soils that are generally unsuitable for SKR. Heavy thatch in this intervening swath would probably prevent inter-core dispersal by SKR in most years, except for the presence of a north-south dirt road that connects the cores at the west end of core area 2 (along the eastern edge of the effluent spray fields). This dirt road is associated with relatively dense concentrations of SKR and is likely used as a dispersal corridor connecting the two core areas. If the road were ever removed in the future, greater consideration would need to be given to managing vegetation and thatch between the cores to facilitate inter-core movements.

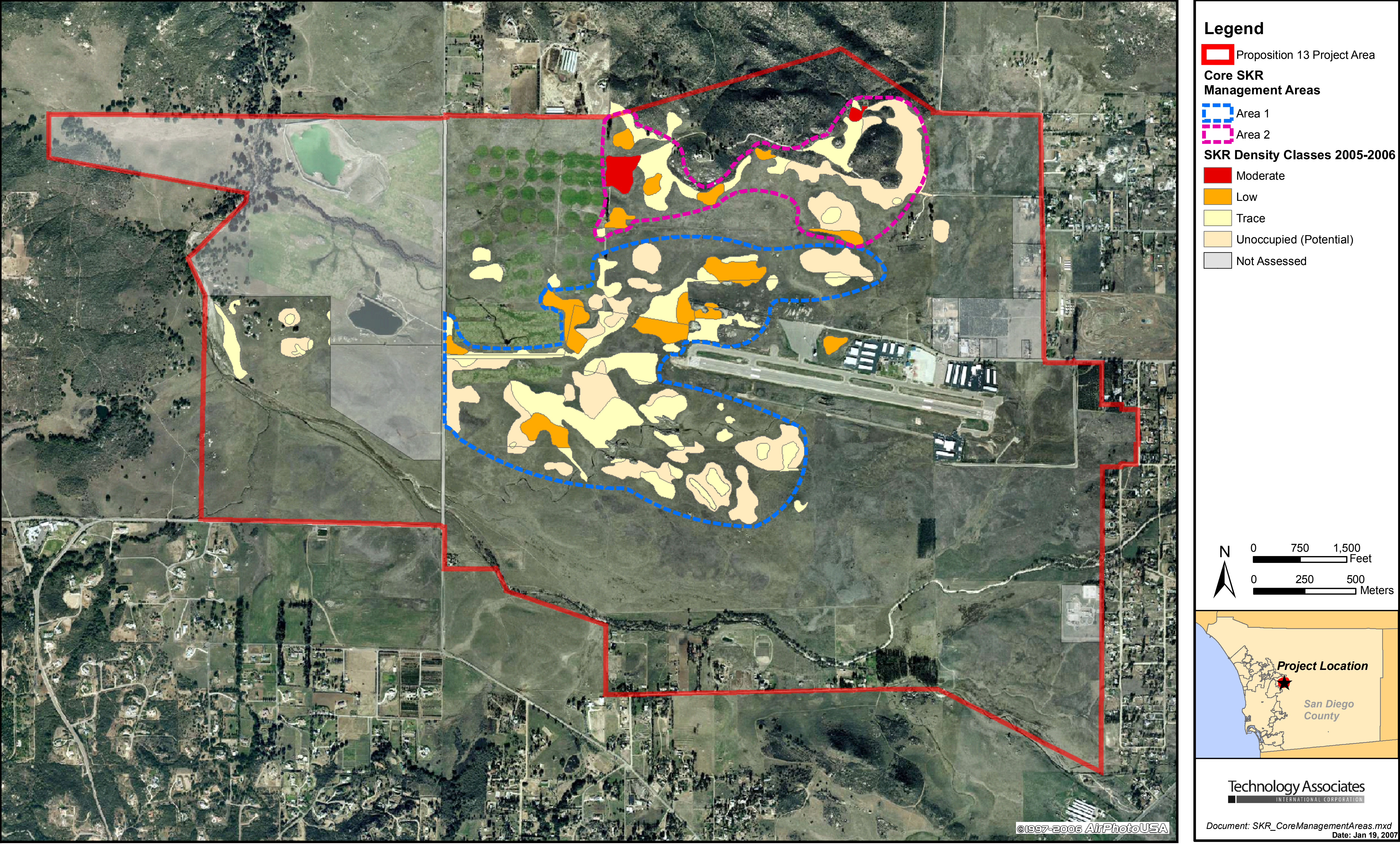


Figure 5 - Core Stephens' Kangaroo Rat Management Areas

Habitat Analyses

Although they had low statistical power due to the low number of vegetation plots that happened to fall within SKR habitat, the analyses of habitat factors reinforced findings of previous studies. During drier years, SKR density is positively correlated with the proportion of bare ground and forb:grass ratio during late summer-fall, and negatively associated with shrub cover and grass cover (O'Farrell and Uptain 1987, Spencer 2003). To a large degree, these vegetation characteristics reflect differences in soil characteristics and degree of disturbance (especially grazing): better-drained soils (and more heavily grazed areas) tend to have more bare ground, less dense grasses, and higher forb:grass ratios than soils with greater clay content (or receiving lesser grazing pressure). However, following winters with heavier than average precipitation, the prolific growth of annual grasses can obscure these differences in habitat quality, as the dense grass growth tends to out-compete forbs and build up a dense thatch layer on a greater range of soil types.

Stronger correlations would likely have been found if not for the following factors:

- Low number of vegetation sample plots that happened to fall within SKR suitable and occupied polygons, and especially for plots falling within higher-value habitat areas. Only 4 vegetation plots in 2005 and 6 in 2006 fell within areas mapped as occupied by SKR, and all of those were mapped at only trace densities. The lack of sample plots falling within higher density and higher quality SKR polygons severely limited the power of statistical tests.
- The extreme growth of annual grasses during 2005, due to heavy rainfall, swamped out the ability to detect habitat differences, especially for measures like bare ground or percent forbs that are known to correlate with habitat value in dry years. The proportion of vegetation plots with bare ground and forbs was exceptionally low during the study period (particularly during 2005) across all plots. During drier years, proportion bare ground generally exceeds 40% and forb:grass ratio exceeds 2:1 during late summer-fall (Spencer 2003).
- Non-linear relationships for some variables may also obscure differences in habitat quality. For example, standing biomass does not increase linearly with the quality of soils to support SKR populations: biomass was higher on loamy soils than on heavy clay soils, so a correlation between biomass and habitat quality was not evident. A more appropriate test would be to have more samples across all classes of loam soils, while eliminating the heaviest clay soils from analysis. In this case, biomass would be expected to increase more linearly with clay content and provide a more meaningful metric for determining thresholds for vegetation management intervention.

Future Monitoring Recommendations

We recommend annual monitoring of the SKR population in the Ramona Grasslands with sufficient rigor and repeatability to trigger vegetation management actions when active management intervention may be required to benefit the population. This need not be overly intensive or expensive. Although it would be ideal to obtain quantitative measures of SKR distribution and abundance at least annually, this could be costly without proportional benefits to the population.

The approach we recommend is to perform sign surveys at many small (or “diffuse”) sampling plots or points that can be revisited annually to determine species presence or absence (along with a visual estimate of burrow density around the point sign is present). This is a form of Percent Area Occupied (PAO) survey, which has become a prominent technique in wildlife population sampling due to its efficiency (Mackenzie et al. 2002, MacKenzie 2005).

This sampling, best done consistently during late summer, would document SKR presence/absence and/or burrow density classes at a sampling of small plots (using GPS) located based on the baseline distribution map (Figure 2). This method primarily utilizes readily obtained presence/absence records for each plot, and plots are typically randomly located in target occupied habitat areas. If, during a particular monitoring year, all or most of these plots were found to be occupied by SKR, lands lying adjacent to original target habitat areas would be inspected to determine if the population had expanded beyond the original area sampled. If a population expansion was confirmed, additional monitoring plots would be established in the newly occupied lands, and future monitoring sessions would include the new plots. This monitoring method, using 50m x 50m plots, has been used to track SKR distribution and abundance at Fallbrook Naval Weapons Station since 2002 (Montgomery et al. 2005). Details of the sampling design should be developed by spring of 2007 and implemented during summer-fall 2007.

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